

Nickel Cadmium Batteries: A Medium for the Study of Metal Whiskers and Dendrites

Anna Cyganowski

Notre Dame Preparatory School, Senior

Dr. Henning Leidecker

NASA GSFC Parts, Packaging & Assembly
Technology Office, Code 562

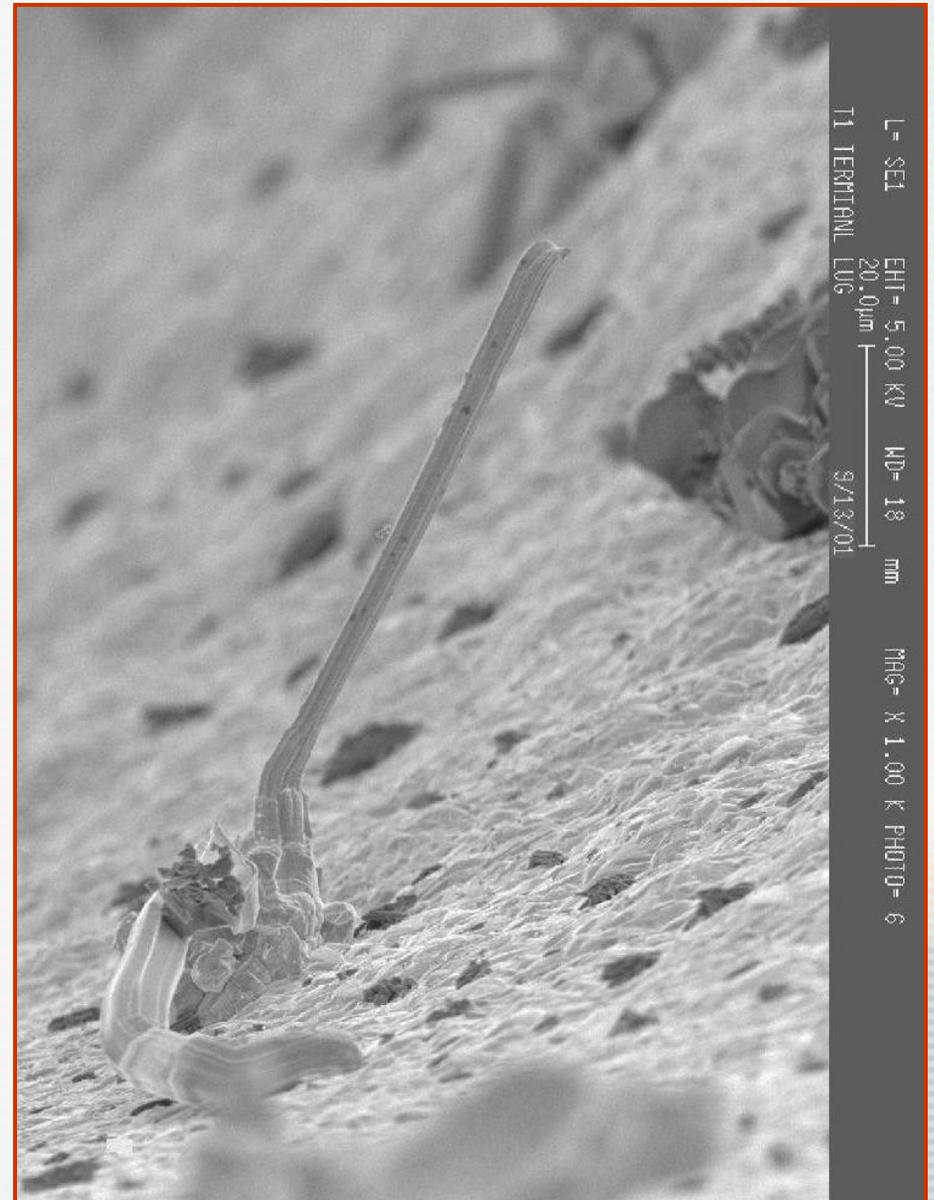
Jay Brusse

QSS Group, Inc. at NASA Goddard

Tin Whisker Telcon – December 6, 2006

Introduction: Metal whiskers

- Tiny metal filaments that conduct electricity
- Are generally observed to grow to lengths of a few millimeters, and sometimes to lengths up to 10 millimeters
- Are microns thick – hard to see optically without proper lighting and magnification
- Mostly grow from thin film deposits of pure metal, such as tin, zinc, and cadmium
- Addition of lead (Pb) to tin films tends to reduce whisker formation

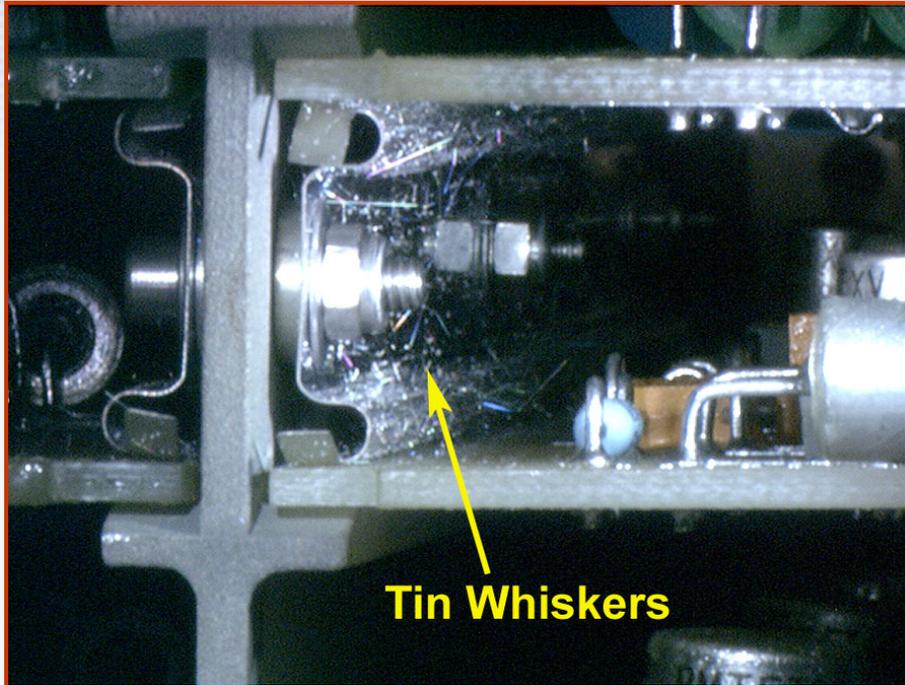


*"Tin Whisker Inside Crimp Barrel of a Terminal Lug",
courtesy of NASA Goddard Space Flight Center*

Introduction: Metal whisker dilemma

- Whiskers pose a serious reliability threat to electronics – electrical shorting can occur
- This problem has been known since the 1940s, yet problems still persist today
- Recent whisker failures have been present in commercial satellites, missiles, nuclear reactors, and watches among others
- Even the July 2006 NASA Space Shuttle Endeavor launch was impacted by the observation of tin whisker formations in other space shuttle flight systems
- European RoHS/WEEE initiative (in effect since July of 2006) bans use of hazardous materials, such as lead (Pb), in electronics – more manufacturers turning to pure tin

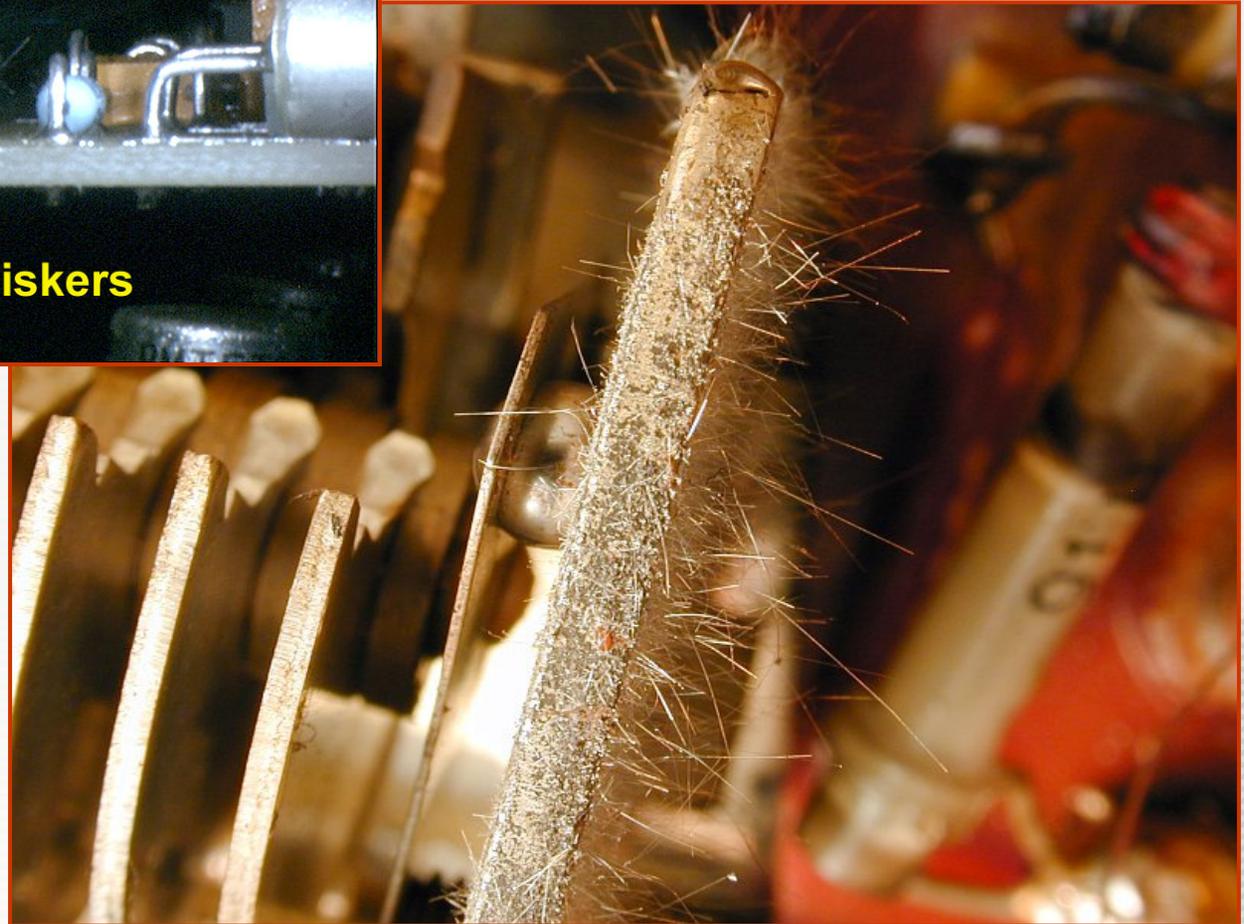
Introduction: Metal Whisker Dilemma



Tin Whiskers

Tin whiskers on variable capacitor, courtesy of NASA Goddard Space Flight Center

Tin whiskers on tin-plated Shuttle card rails, courtesy of D. McCorvey, March 2006



More Dangerous Little Critters

Zinc whiskers on hot dip galvanized steel pipe, Courtesy of NASA Goddard Space Flight Center



Application to nickel cadmium batteries

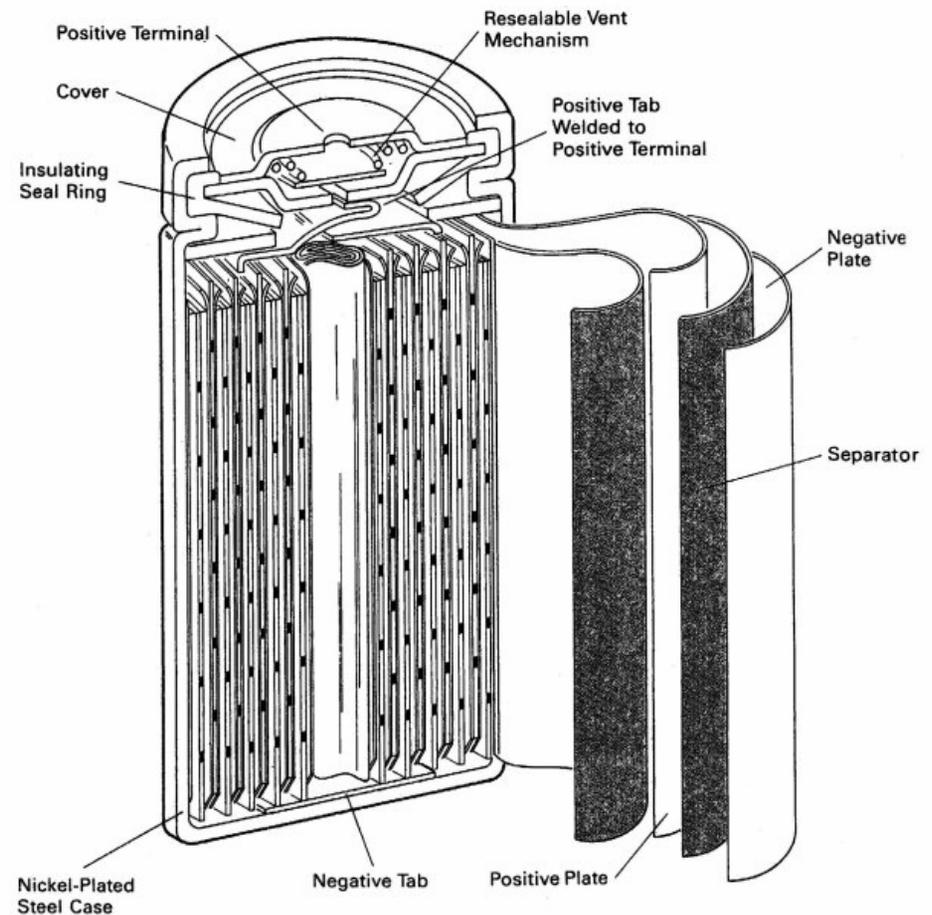
- There have been claims that NiCd cells fail prematurely due to metal “growths”
 - An example can be found here:
<http://www.uoguelph.ca/~antoon/gadgets/rejuv.html>
- No scientific literature is readily provided about the topic, and terms such as “whiskers”, “dendrites”, and “crystals” are used interchangeably to refer to these growths
- Growths short out the cell – revival techniques are designed to “fuse out” the growths
- New medium for the study of cadmium whiskers?

Research Objectives

- Determine whether metal growths in nickel cadmium cells exist
- Verify whether the growths are whiskers, dendrites, or another type of metal formation
- Find out an application of this research to metal whisker research as a whole

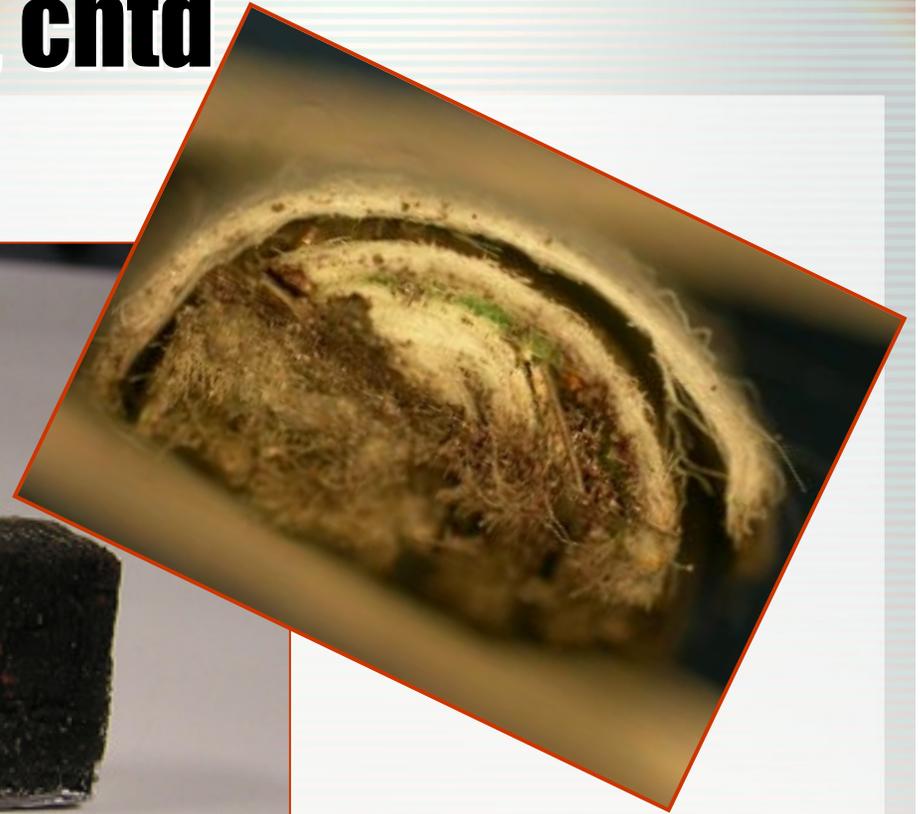
Background: Anatomy of a NiCad cell

- Nickel acts as the positive electrode, while cadmium acts as the negative electrode
- Solution of potassium hydroxide (KOH) acts as the electrolyte
- Porous separator material is a combination of polypropylene and polyamide (Nylon)
- Metal growths are said to form from the cadmium electrode, where it bridges the separator to the nickel and shorts the cell



Nickel cadmium battery diagram, courtesy of Radio Shack

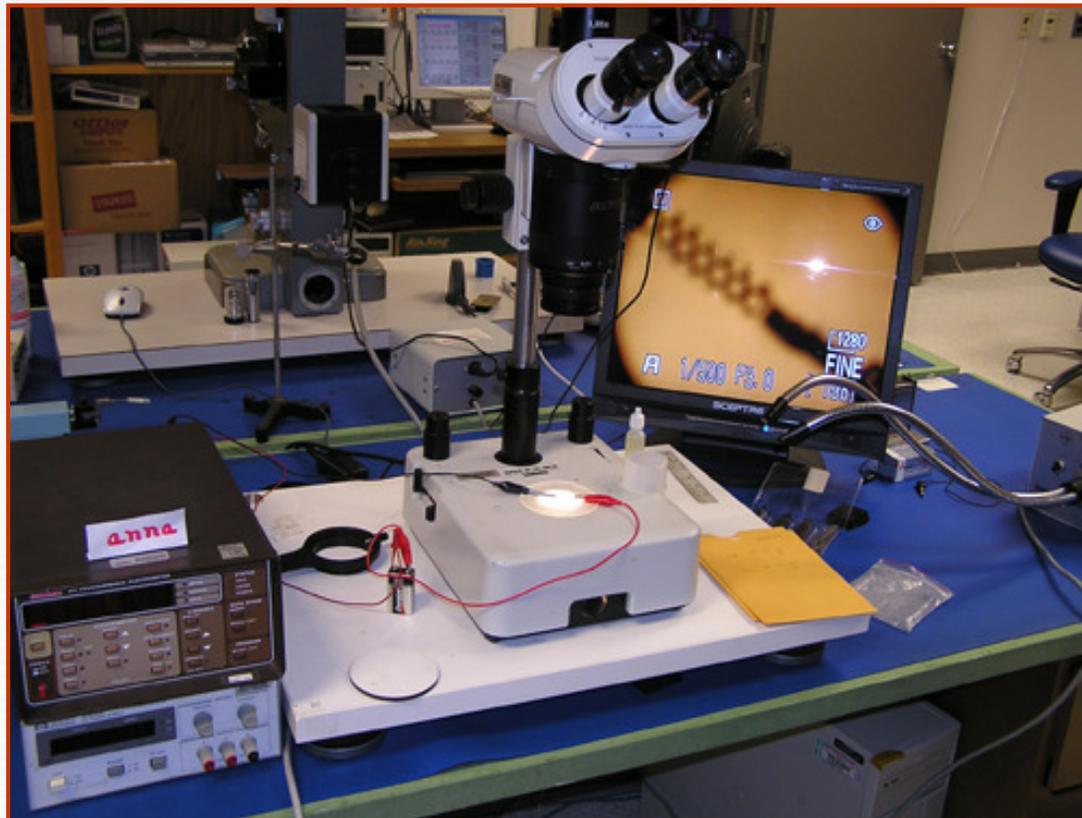
Anatomy of a NiCd cell, cntd



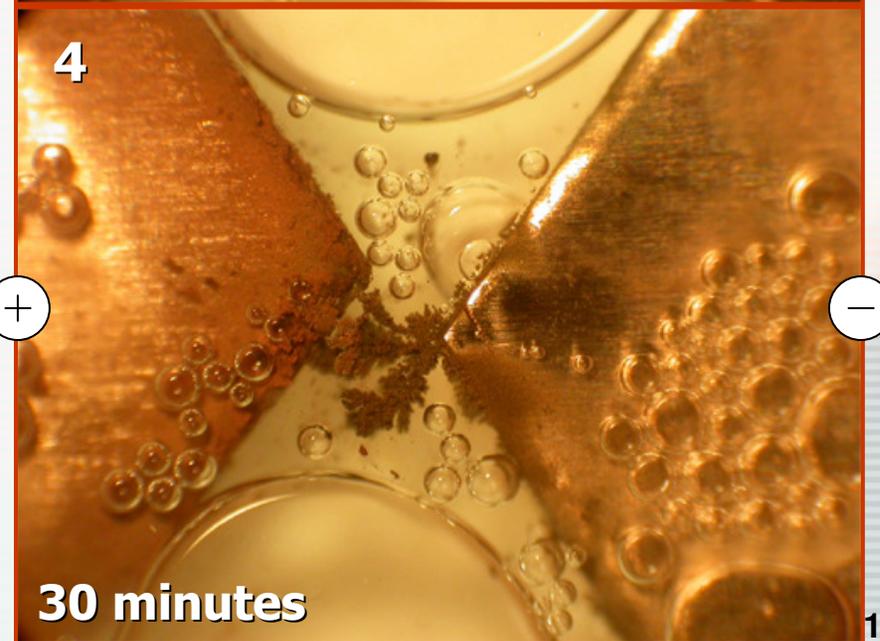
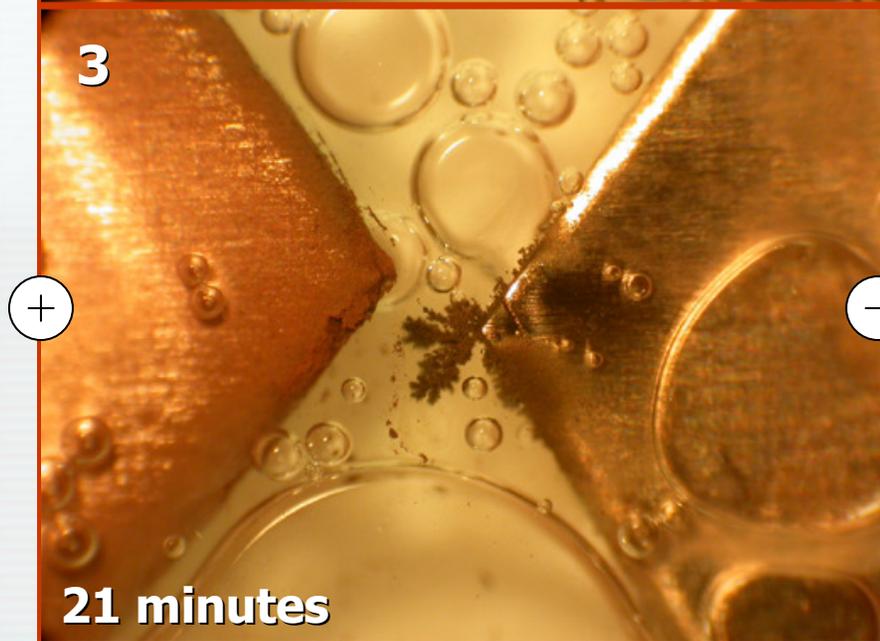
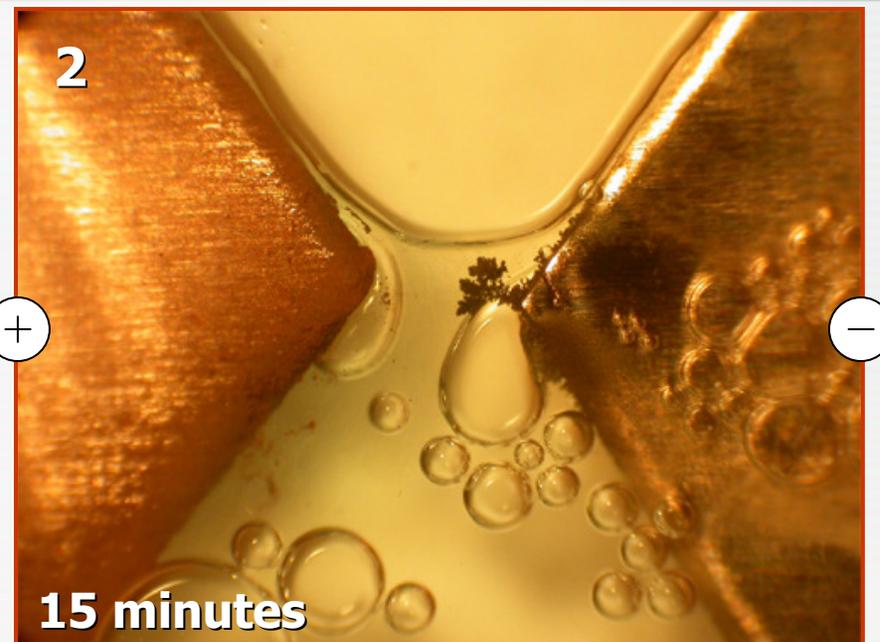
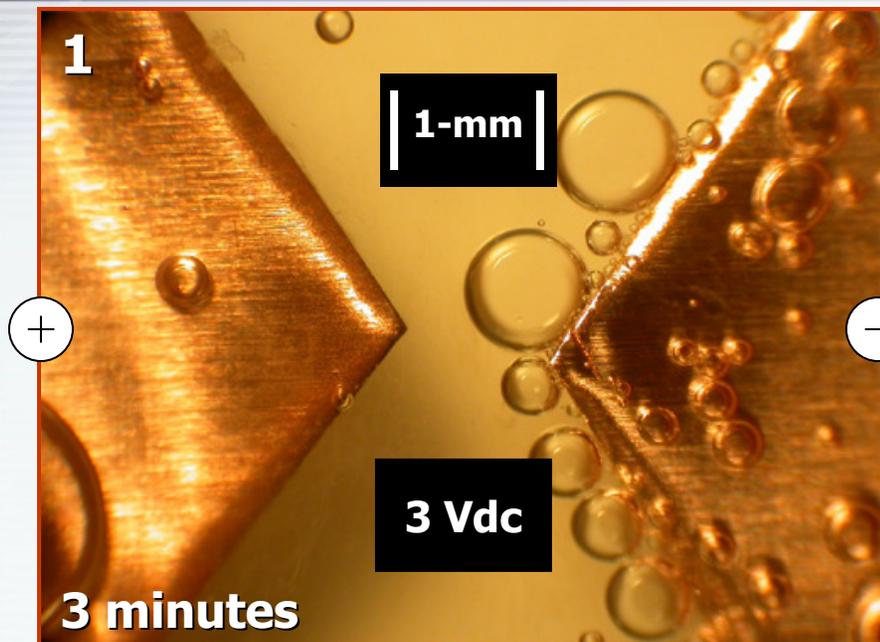
- Approximately 10-year-old Sanyo Cadnica cell
- Found no apparent metallic formations during optical inspection

Experiment #1: Running an electrochemical cell

- Purpose: to examine the workings of an electrochemical cell and to watch for metal growths
- Materials used: copper tape pieces, citric acid solution with detergent, AA 1.5V battery cells, ammeter



Running an electrochemical cell, cntd.



Running an electrochemical cell, cntd.

Video of copper dendrite formation can be found here:

<http://nepp.nasa.gov/whisker/dendrite/>

Differences between whiskers and dendrites

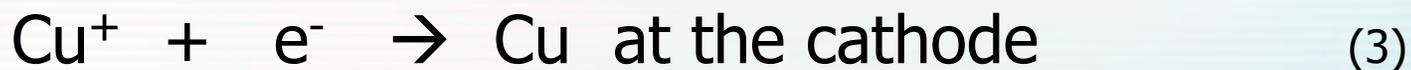
Whiskers are very thin filaments that protrude outward from a surface (z-axis)

- Exact growth mechanisms are yet unknown

Dendrites form in fern-like or snowflake-like patterns across a surface (x-y plane)

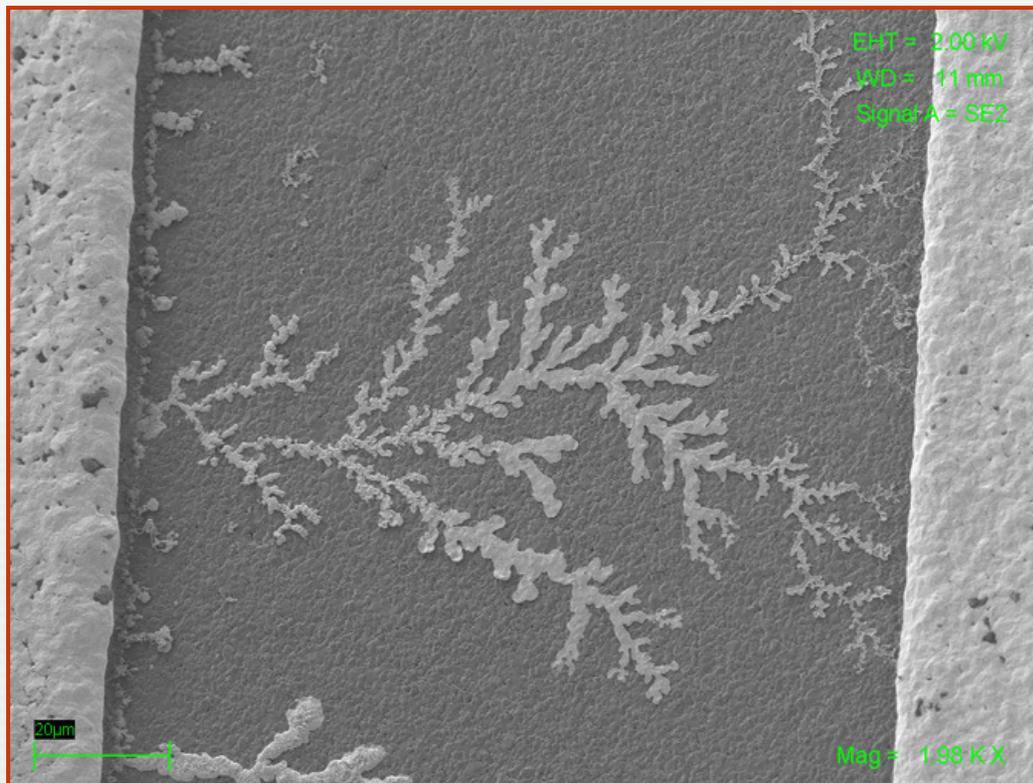
- Require a solvent capable of dissolving metal into a solution of metal ions
- Ions are redistributed through electromigration in the presence of an electric field

Reactions in Experiment #1:



Whiskers and dendrites, ctnd.

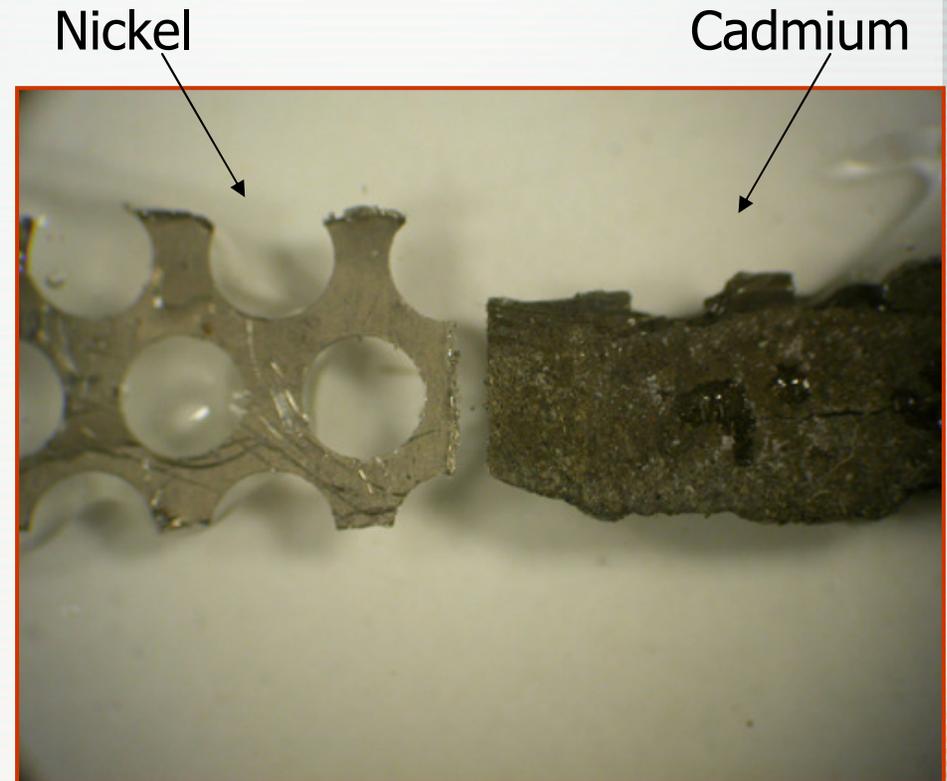
Silver dendrite growing in failed part, courtesy of NASA Goddard Space Flight Center



Metal whisker, courtesy of NASA Goddard Space Flight Center

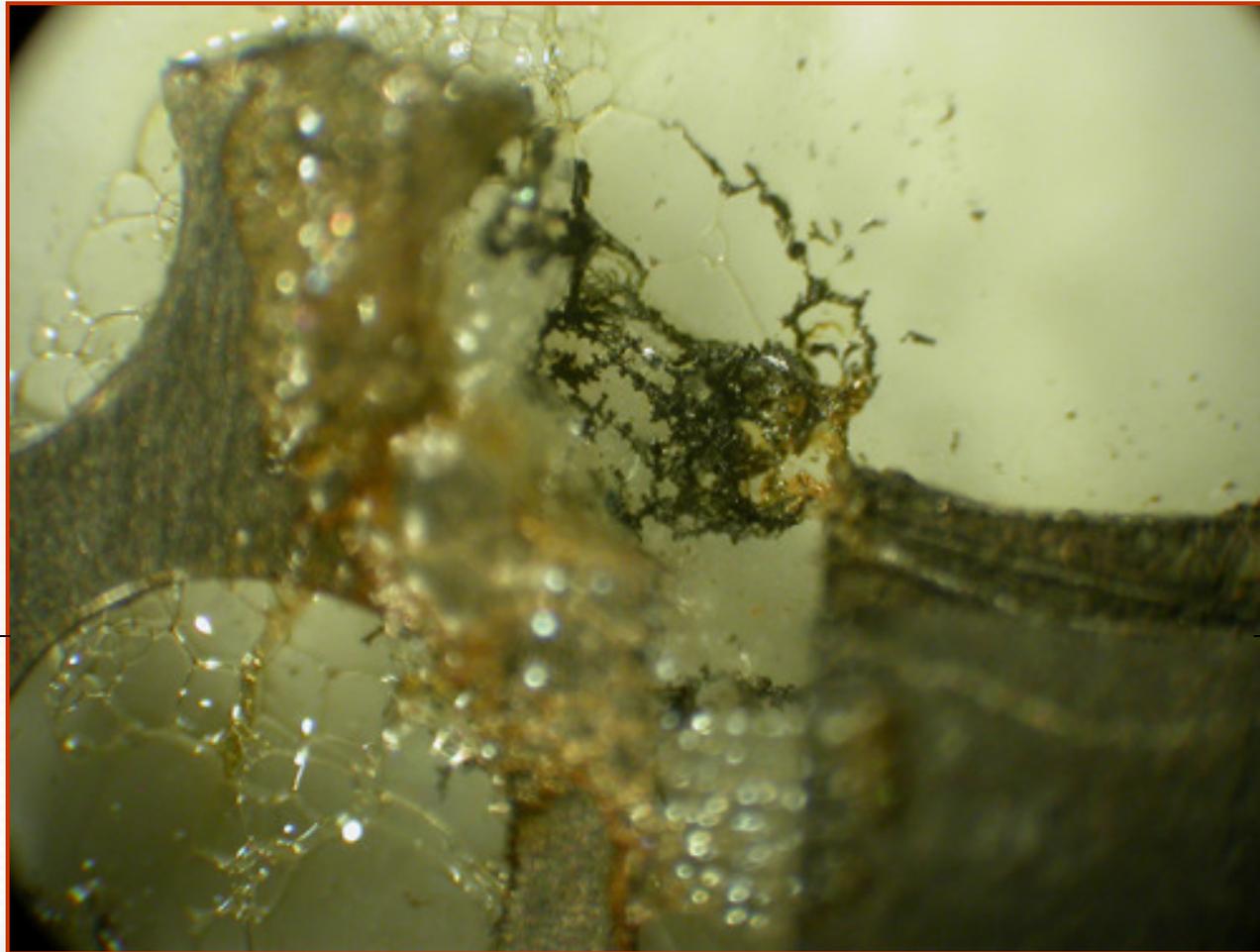
Experiment #2: Simulating NiCd growths

- Purpose: to create a scenario in which metal growths would form in a NiCd cell
- Electrodes were harvested and used from a disassembled NiCd cell
- 9V battery was used as the power source



Simulating NiCd growths, cntd.

- Citric acid solution was applied, and a large dendrite grew from the negative electrode, touching the positive electrode within minutes



Conclusions

- It is very plausible that NiCds – as electrochemical cells – form metal growths, particularly dendrites
- No evidence of whiskers was found, but that does not prove their absence in NiCd cells

Areas for future work

- Find evidence of dendritic growths in NiCd cells using improved inspection techniques
- Repeat dendritic growth experiments using electrolytes commonly found in NiCd cells (e.g. potassium hydroxide, KOH)
- Investigate prevention methods for dendrites in NiCd cells
- Research dendrites of other metals (e.g. silver) and their role in electronic part failures

Thank You Very Much!!!

